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DO FAST OLDER RUNNERS PACE DIFFERENTLY FROM FAST YOUNGER RUNNERS IN THE 'NEW YORK CITY MARATHON'?

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Abstract

Although pacing strategies in the marathon and generally in endurance running have been well studied with regards to the effects of age group and performance level, little is known for their interaction. Thus, the aim of the present study was to examine whether fast runners of different age differ for pacing. Finishers (women, *n*=117,595; men, *n*=180,487) in the 'New York City' marathon between 2006 and 2016 were analyzed in 5-year age groups. To examine the effect of performance, we created performance groups according to quartiles of average race speed (Q1 - the fastest, Q2, Q3 and Q4 - the slowest). A large main effect of split on race speed was observed in women and men with the fastest speed in the 5-10 km split and the slowest in the 35-40 km. Compared to the other performance groups, the slowest group had the largest % decrease in speed at 5 km, 10 km, 15 km and 20 km but the largest % increase in speed at 35 km and 40 km. The fastest group had the least decrease during the race and the least increase at 40 km. A trivial split×age group interaction on race speed was observed for all performance groups in both sexes. This interaction was more pronounced in Q4. Based on these findings, coaches should advise their slow master runners to adopt age-tailored pacing strategy, whereas their fast master runners should adopt similar pacing as the younger fast runners.

Key words: age, quartile, performance, master athlete, endurance

INTRODUCTION

The 'New York City' Marathon (NYCM) is one of the most popular running races held annually. The successful participation in this race depends on physiological and psychological parameters, such as anaerobic threshold and motivation, respectively (19). During the last decade, an increased scientific interest has been observed with regards to another performance-related factor in marathon, namely pacing. Optimal pacing can contribute to performance improvements (3).

Pacing has been defined as change of speed across a race or the ability to appropriately distribute energy to prevent premature fatigue before the completion of the event (21) and several methods of its calculation have been suggested (5, 16, 23). For instance, it is estimated as the percentage change in speed in the second half of a marathon compared to the first half (5), the mean speed in the last 12.2 km divided by the mean speed of the first 30 km (23) or the mean speed in the last 9.7 km divided by the mean speed of the first 32.5 km (16). Independently of its assessment method, previous research has highlighted its association with sex, age and performance (20). Today, it has been well established that women, older and faster runners adopt less variable pacing than men, younger and slower runners (5, 23).

However, we have no knowledge whether differences between younger and older marathon runners of similar performance level in pacing exist. Only one study has ever examined the age×performance interaction on race speed and their finding of no interaction might be due to the relatively small number of participants (n=319) (16). Considering the popularity of marathon running, and particularly of the NYCM, such knowledge would be of great practical importance for runners and coaches, especially in the case that a coach train runners of similar level but different age.

Therefore, the aim of this study was to investigate whether differences in pacing strategies do exist between younger and older marathon runners of similar performance level. We hypothesized to find differences in pacing between fast younger and fast older finishers. Particularly, since fast older finishers would be slower than fast younger finishers, and fast finishers would be pace more evenly than slower finishers, we would expect younger fast finishers to pace relatively more evenly than older fast finishers.

METHODS

Experimental Approach to the Problem

To test our hypothesis, all women and men who finished the NYCM between 2006 and 2016 were considered. All data were obtained from the official website of the NYCM (www.tcsnycmarathon.org/).

Subjects

Split times and overall race times of all female and male finishers of all age groups were collected. Before 2006, no split times were available. All procedures used in the study were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland with a waiver of the requirement for informed consent of the participants given the fact that the study involved the analysis of publicly available data.

Procedures

All finishers (women, n=168,702; men, n=282,935) were considered in the present analysis. Inclusion criteria were that for each finisher there were complete data of all split times and changes between splits were less than 20%. The limit of 20% was set to avoid the influence of cases with "abnormal" speed fluctuations (e.g. change from high speed running to slow walking indicating excessive fatigue or injury) on pacing. Those who met these criteria (women, n=117,595, i.e. 69.7% of the initial sample; men, n=180,487, i.e. 63.8%) were analyzed (**Table 1**) in 5-year age groups. Nine splits were analyzed: 0-5 km, 5-10 km, 10-15 km, 15-20 km, 20-25 km, 25-30 km, 30-35 km, 35-40 km and 40-42 km. In addition, eight points of change of speed were considered: 5 km, 10 km, 15 km, 20 km, 25 km, 30 km, 35 km and 40 km. The NYCM is a relative flat race course and presents relatively small changes in its elevation (www.tcsnycmarathon.org/sites/default/files/NYC%20Marathon%20Elevation%20Profile_2014.pdf). It starts at an elevation of 29.3 m, decreases by -8.0 m in the 0-5 km split and by -9.1 m in the 5-10 km split, increases by +1.8 m in the 10-15 km split, decreases by -3.6 m in the 15-20 km split, increases by +30.7 m in the 20-25 km split, decreases by -39.0 m in the 25-30 km split, and then increases continuously in the 30-35 km (+6.1 m), 35-40 km (+13.7 m) and 40-42 km split (+3.7 m) to end at an elevation of 25.6 m.

Statistical Analyses

The statistical packages IBM SPSS v.20.0 (SPSS, Chicago, USA) and GraphPad Prism v. 7.0 (GraphPad Software, San Diego, USA) were used to perform all statistical analyses. Descriptive statistics (mean±standard deviation) were used for all variables. Race speed was calculated by dividing split distance (*i.e.* 5 km for all splits, except the last one which was 2.195 km) by time for each split (19). We created performance groups according to quartiles of average race speed (Q1 - the fastest, Q2, Q3 and Q4 - the slowest) in total and within each age group. This approach allowed a 'relative' comparison among age groups, *e.g.* the faster 50-54 years athletes were compared with the faster 20-24 years athletes for pacing; however, we acknowledged that these groups differed for performance. A two-way ANOVA examined the main effects of sex, age group, performance group and split, and the performance group×split and performance group×age group interaction on race speed, followed by a Bonferroni post-hoc analysis. The magnitude of differences in the ANOVA was evaluated using eta squared (η^2) as trivial ($\eta^2<0.01$), small ($0.01\leq\eta^2<0.06$), moderate ($0.06\leq\eta^2<0.14$) and large ($\eta^2\geq0.14$) (4). We calculated percentage changes of speed at eight points of the race, *e.g.* change at 5 km (%) = 100 × (speed in 5-10 km − speed in 0-5 km) / speed in 0-5 km. We defined an end spurt as change speed at 40 km >0% and examined the association of end spurt with sex, age and performance using chi square (χ^2) and Cramer's phi (φ). Alpha level was set at 0.05.

RESULTS

Race speed by split and performance group

A large main effect of split on race speed was observed in women ($p<0.001$, $\eta^2=0.557$; **Figure 1A**) and men ($p<0.001$, $\eta^2=0.591$; **Figure 1B**). In both sexes, the fastest speed was shown in the 5-10 km split and the slowest in the 35-40 km. A small split×performance group interaction on race speed was found in women and men ($p<0.001$, $\eta^2=0.044$) indicating differences in pacing by performance group. Particularly, a different trend was observed between the first and the last splits; compared to the other performance groups, the slowest group had the largest % decrease in speed at 5 km, 10 km, 15 km and 20 km but the largest % increase in speed at 35 km and 40 km (**Figure 2**).

Race speed by split and age group

In women, a trivial split×age group interaction on race speed was observed for Q1 ($p<0.001$, $\eta^2=0.005$), Q2 ($p<0.001$, $\eta^2=0.005$), Q3 ($p<0.001$, $\eta^2=0.005$) and Q4 ($p<0.001$, $\eta^2=0.007$) (**Figure 3**). In men, a trivial split×age group interaction on race speed was shown for Q1 ($p<0.001$, $\eta^2=0.003$), Q2 ($p<0.001$, $\eta^2=0.005$), Q3 ($p<0.001$, $\eta^2=0.007$) and Q4 ($p<0.001$, $\eta^2=0.007$) (**Figure 4**). In both sexes, the age group×performance interaction was more pronounced in Q4 (**Figure 5** and **6**). For instance, the Q4 older age groups increased speed at 25 km more than the Q4 younger age groups; however, the Q4 older age groups increased speed at 40 km less than the Q4 younger age groups.

End spurt

An end spurt×sex association was observed with larger prevalence of end spurt in women (85.4%) than in men (74.7%; $\chi^2=4880.062$, $p<0.001$, $\varphi=-0.128$) (**Figure 7**). In addition, an end spurt×quartile association was shown in both sexes (women, $\chi^2=425.388$, $p<0.001$, $\varphi=0.060$; men, $\chi^2=2.760.401$, $p<0.001$, $\varphi=0.124$). According to this association, the largest prevalence was found in Q3 in women (88.3%) and Q4 in men (82.0%) and the lowest in Q1 in both sexes (82.3% and 67.1%, respectively), i.e. there was lower prevalence of end spurt in the faster performance groups. In women, an end spurt×age group was observed in Q1 ($\chi^2=38.282$, $p<0.001$, $\varphi=0.036$), Q2 ($\chi^2=40.641$, $p<0.001$, $\varphi=0.037$), Q3 ($\chi^2=73.101$, $p<0.001$, $\varphi=0.050$) and Q4 ($\chi^2=144.499$, $p<0.001$, $\varphi=0.070$). In men, an end spurt×age group was observed in Q1 ($\chi^2=26.172$, $p=0.016$, $\varphi=0.024$), Q2 ($\chi^2=91.495$, $p<0.001$, $\varphi=0.045$), Q3 ($\chi^2=112.364$, $p<0.001$, $\varphi=0.050$) and Q4 ($\chi^2=84.664$, $p<0.001$, $\varphi=0.043$).

DISCUSSION

The main findings of the present study were that (*i*) a large main effect of split on race speed was observed in women and men with the fastest speed in the 5-10 km split and the slowest in the 35-40 km; (*ii*) compared to the other performance groups, the slowest group had the largest % decrease in speed at 5 km, 10 km, 15 km and 20 km but the largest % increase in speed at 35 km and 40 km; (*iii*) the fastest group had the least decrease during the race and the least increase at 40 km; (*iv*) a trivial split×age group interaction on race speed was observed for all performance groups in both sexes; and (*v*) the split×age group interaction was more pronounced in Q4.

The novel finding of the present study was the performance×age interaction on pacing. The different pacing among runners with similar 'relative' (quartiles) performance level but different age should be attributed mostly to their performance. For instance, the comparison between younger and older Q1 reflects differences between fast and slow runners, since younger runners are faster than their older counterparts (5, 6). Furthermore, it has been shown that fast runners adopt a relatively more even pace compared to slow runners (5). Consequently, we observed in the younger Q1 a more even pacing compared to the older Q1. Thus, it was concluded that the origin of the differences in pacing among runners with similar performance level but different age was the age-related variation of the physiological and training characteristics associated with the performance in marathon. For instance maximal oxygen uptake declines by 10% per decade due to both central and peripheral changes, *e.g.* decrease of maximal heart rate and lean body mass (12), and aging results in changes in fiber type, i.e. increase of type I fibers percentage (15). Age-related muscle atrophy appears at ~50 years and this might impact older runners (7).

In addition, the older runners might not be able to maintain the same volume and intensity of training (7).

Considering the classification of pacing into negative, all-out, positive, even, parabolic-shaped and variable (1), the pattern of pacing in the present study was characterized as positive, *i.e.* finishers increased the time spent in each split across the race (their speed decreased). The positive pacing of the finishers in the present study was not in agreement with that of elite (medalists) runners competing in Olympic and IAAF World Championship marathons that showed the maintenance of an even-paced running from 10 km onwards (11). This disagreement should be attributed to the runners' performance level since we observed in the present study that the fastest runners adopted a relatively more even pacing compared to the slower runners. On the other hand, our findings confirmed those of a previous study on the NYCM that characterized the pacing of all performance groups as positive accompanied by less variability in speed across the race in the fastest runners (20). Moreover, a positive pacing was found in an analysis of 14 USA marathons (5), where the second half was slower than the first one. The least variability in speed observed in the fastest runners could be partially due to their greater experience (5).

In contrast to the increase of speed at 5 km and 25 km, which were explained mostly by the decrease of elevation, the increase of speed at 40 km should be attributed solely to an end "spurt" since no remarkable change in elevation is noticed during 40-42 km. An end spurt is part of the pacing during a race. An athlete who is able to save energy during the race for an end spurt paces differently compared to an athlete who is not able to perform an end spurt. The occurrence of an end spurt might be due to psychological factors. Pacing is a combination of anticipation, knowledge of the end-point, prior experience and sensory feedback (21). The knowledge of the near finish might motivate the runners to mobilize the last reserves. The observation of an end 'spurt' was in agreement with previous studies in other endurance running distances and sports. An end spurt has also been reported for 100 km ultra-marathoners competing in the '100 km Lauf Biel' (13), ultra-marathoners competing in 101 km and 161 km (22), but also for shorter distances, such as 1 mile (18). An end spurt has also been reported for master freestyle swimmers (17).

The presence of the end spurt suggests that the pacing strategy is regulated 'in anticipation' and is not purely the result of a developing 'peripheral fatigue' (18). Another explanation of the larger changes in speed observed in the slower runners might be the current recommendations for novice runners, according to which large changes in speed such as alternating run and walk are advised for a successful finish time (2).

A major finding was the split×performance group interaction on race speed, according to which, compared to the other performance groups, the slowest group had the largest % decrease in speed at 5 km, 10 km, 15 km and 20 km and the largest % increase in speed at 35 km and 40 km, whereas the fastest group had the least decrease during the race and the least increase at 40 km. That is, fast runners maintained a relatively more even pacing compared to slow runners, which was in agreement with previous research in marathon (5, 6, 9, 16, 20), but also in other running distances such as half-marathon (10), 100 km ultra-marathon (13, 14). For instance, it has been shown that the fastest runners paced evenly throughout marathon, whereas slower runners slowed especially after 20-25km (6). Moreover, faster runners showed lower variability of pace compared to slower marathon runners in other studies (9, 20).

We also need to consider the aspect of experience in pacing. It has been shown for marathoners that greater experience was associated with lesser slowing (5). The faster runners probably have more experience in training for and running marathons. For the slower runners finishing is the goal for most, so they might not be too concerned with the amount of time it takes to get to Central Park as their pacing strategy and just want to get to the Park to run to the finish line.

The main limitation of the present study was the definition of performance groups, which relied on quartiles. Thus, the comparison of a particular quartile (*e.g.* Q1) among age groups implied that these groups differed in absolute performance (*i.e.* race time). A further limitation is the fact that we have not analyzed the non-finishers. Unfortunately, the non-finishers are not recorded in the race results. Most probably, the non-finishers had a failed pacing strategy or some kind of injury stopped their effort.

On the other hand, a strength of the study was that this 'relative' approach in performance allowed the comparison of more even groups (19, 20). Instead, if we created performance groups according to race time, it would not be possible to consider all age groups, because the older one would miss very fast race times. Although coaches and runners would be more interested in the performance analysis by performance groups based on race time (e.g. finishers in 3-4 h *versus* finishers in 4-5 h), the analysis by quartiles was more appropriate to examine differences in pacing among age groups.

PRACTIAL APPLICATIONS

It is well established that pacing can influence race time in marathon running and that sex, age and performance level have been identified as correlates of pacing. However, limited information existed with regards to the age×performance interaction, *i.e.* whether marathon runners of similar performance level but different age pace differently. Our analysis indicated statistical significant age×performance interaction on pacing, which was of trivial magnitude. Despite the trivial magnitude, great practical implications are derived from the findings of the present study. The age×performance interaction was more pronounced in the slowest performance group, whereas less variability was observed in the fastest group. For instance, the slower older age groups increased speed at 25 km more than the slower younger age groups, whereas they increased speed at 40 km less. Furthermore, the differences in pacing among age groups with similar performance might level vary across race being more pronounced at 5km, at the middle of the race and 40 km. Based on these findings, coaches should advise their slow master runners to adopt age-tailored pacing strategy, whereas their fast master runners should adopt similar pacing as the younger fast runners.

References

1. Abbiss CR and Laursen PB. Describing and understanding pacing strategies during athletic competition. *Sports Med* 38: 239-252, 2008.
2. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc* 30: 975-991, 1998.
3. Angus SD. Did recent world record marathon runners employ optimal pacing strategies? *J Sports Sci* 32: 31-45, 2014.
4. Cohen J. *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.
5. Deaner RO, Carter RE, Joyner MJ, and Hunter SK. Men are more likely than women to slow in the marathon. *Med Sci Sports Exerc* 47: 607-616, 2015.
6. Ely MR, Martin DE, Cheuvront SN, and Montain SJ. Effect of ambient temperature on marathon pacing is dependent on runner ability. *Med Sci Sports Exerc* 40: 1675-1680, 2008.
7. Faulkner JA, Davis CS, Mendias CL, and Brooks SV. The aging of elite male athletes: age-related changes in performance and skeletal muscle structure and function. *Clin J Sport Med* 18: 501-507, 2008.
8. Foster C, Wright G, Battista RA, and Porcari JP. Training in the aging athlete. *Curr Sports Med Rep* 6: 200-206, 2007.
9. Haney TA, Jr. and Mercer JA. A Description of variability of pacing in marathon distance running. *Int J Exerc Sci* 4: 133-140, 2011.

10. Hanley B. Pacing profiles and pack running at the IAAF World Half Marathon Championships. *J Sports Sci* 33: 1189-1195, 2015.

11. Hanley B. Pacing, packing and sex-based differences in Olympic and IAAF World Championship marathons. *J Sports Sci* 34: 1675-1681, 2016.

12. Hawkins S and Wiswell R. Rate and mechanism of maximal oxygen consumption decline with aging: implications for exercise training. *Sports Med* 33: 877-888, 2003.

13. Knechtle B, Rosemann T, Zingg MA, Stiefel M, and Rust CA. Pacing strategy in male elite and age group 100 km ultra-marathoners. *Open Access J Sports Med* 6: 71-80, 2015.

14. Lambert MI, Dugas JP, Kirkman MC, Mokone GG, and Waldeck MR. Changes in running speeds in a 100 km ultra-marathon race. *J Sports Sci Med* 3: 167-173, 2004.

15. Maharam LG, Bauman PA, Kalman D, Skolnik H, and Perle SM. Masters athletes: factors affecting performance. *Sports Med* 28: 273-285, 1999.

16. March DS, Vanderburgh PM, Titlebaum PJ, and Hoops ML. Age, sex, and finish time as determinants of pacing in the marathon. *J Strength Cond Res* 25: 386-391, 2011.

17. Nikolaidis PT and Knechtle B. Pacing in age-group freestyle swimmers at The XV FINA World Masters Championships in Montreal 2014. *J Sports Sci* 35: 1165-1172, 2017.

18. Noakes TD, Lambert MI, and Hauman R. Which lap is the slowest? An analysis of 32 world mile record performances. *Br J Sports Med* 43: 760-764, 2009.

19. Renfree A and St Clair Gibson A. Influence of different performance levels on pacing strategy during the Women's World Championship marathon race. *Int J Sports Physiol Perform* 8: 279-285, 2013.

20. Santos-Lozano A, Collado P, Foster C, Lucia A, and Garatachea N. Influence of sex and level on marathon pacing strategy. Insights from the New York City Race. *Int J Sports Med* 35: 933-938, 2014.

21. Skorski S and Abbiss CR. The manipulation of pace within endurance sport. *Front Physiol* 8: 102, 2017.

22. Tan PLS, Tan FHY, and Bosch AN. Similarities and differences in pacing patterns in a 161-km and 101-km ultra-distance road race. *J Strength Cond Res* 30: 2145-2155, 2016.

23. Trubee NW, Vanderburgh PM, Diestelkamp WS, and Jackson KJ. Effects of heat stress and sex on pacing in marathon runners. *J Strength Cond Res* 28: 1673-1678, 2014.

Table 1 Number of participants by sex and age group

Age group	Women (*n*)	Men (*n*)	Total (*n*)
<20	295	415	710
20-24	4,379	3,688	8,067
25-29	18,822	14,788	33,610
30-34	21,156	24,412	45,568
35-39	19,484	30,147	49,631
40-44	20,088	35,340	55,428
45-49	14,993	28,151	43,144
50-54	10,614	22,491	33,105
55-59	4,733	11,312	16,045
60-64	2,142	6,425	8,567
65-69	628	2,210	2,838
70-74	205	842	1,047
75-79	42	222	264
80-84	14	44	58
Total	117,595	180,487	298,082

Legends of figures

Figure 1 Race speed by split and performance group in women (A) and men (B). Error bars represent standard deviations. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest.

Figure 2 Changes in speed (Δspeed, %) by distance and performance group in women (a) and men (b). Error bars represent standard deviations. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest.

Figure 3 Race speed by split, age group and performance in women. Error bars represent standard errors. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest. Age groups are depicted from <20 (left) to 80-84 (right) for each split.

Figure 4 Race speed by split, age group and performance in men. Error bars represent standard errors. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest. Age groups are depicted from <20 (left) to 80-84 (right) for each split.

Figure 5 Changes in speed (%) by distance, age group and performance in women. Error bars represent standard errors. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest. Age groups are depicted from <20 (left) to 80-84 (right) for each distance.

Figure 6 Changes in speed (%) by distance, age group and performance in men. Error bars represent standard errors. Q1, Q2, Q3 and Q4 are quartiles of performance (race time) with Q1 the fastest. Age groups are depicted from <20 (left) to 80-84 (right) for each distance.

Figure 7 End spurt by sex, age group and performance group. W=women; M=men; Q1, Q2, Q3, Q4= quartiles of performance (race time) with Q1 the fastest; the solid and dashed lines represent mean score of end spurt in women and men, respectively.

Figure 1

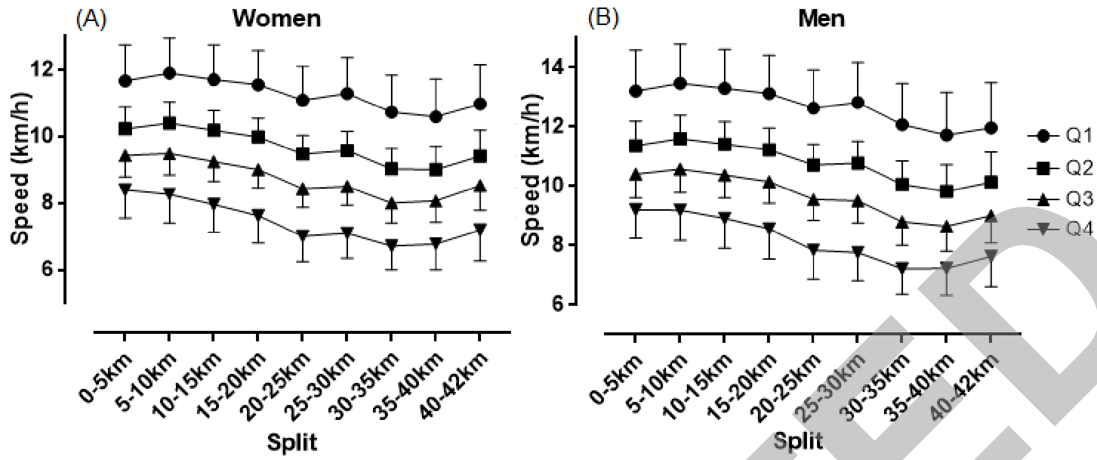
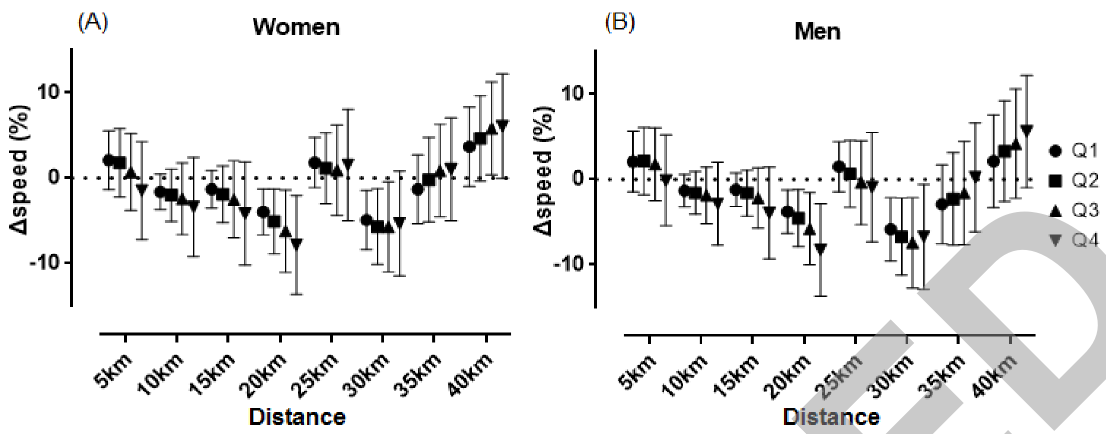

(A)
Women
Speed (km/h)
12
10
8
6
0-5km
5-10km
10-15km
15-20km
20-25km
25-30km
30-35km
35-40km
40-42km
Split
(B)
Men
Speed (km/h)
14
12
10
8
6
0-5km
5-10km
10-15km
15-20km
20-25km
25-30km
30-35km
35-40km
40-42km
Split
Q1
Q2
Q3
Q4

Figure 2



(A)
Women
Δspeed (%)
10
0
-10
5km
10km
15km
20km
25km
30km
35km
40km
Distance
(B)
Men
Δspeed (%)
10
0
-10
5km
10km
15km
20km
25km
30km
35km
40km
Distance
Q1
Q2
Q3
Q4

Figure 3

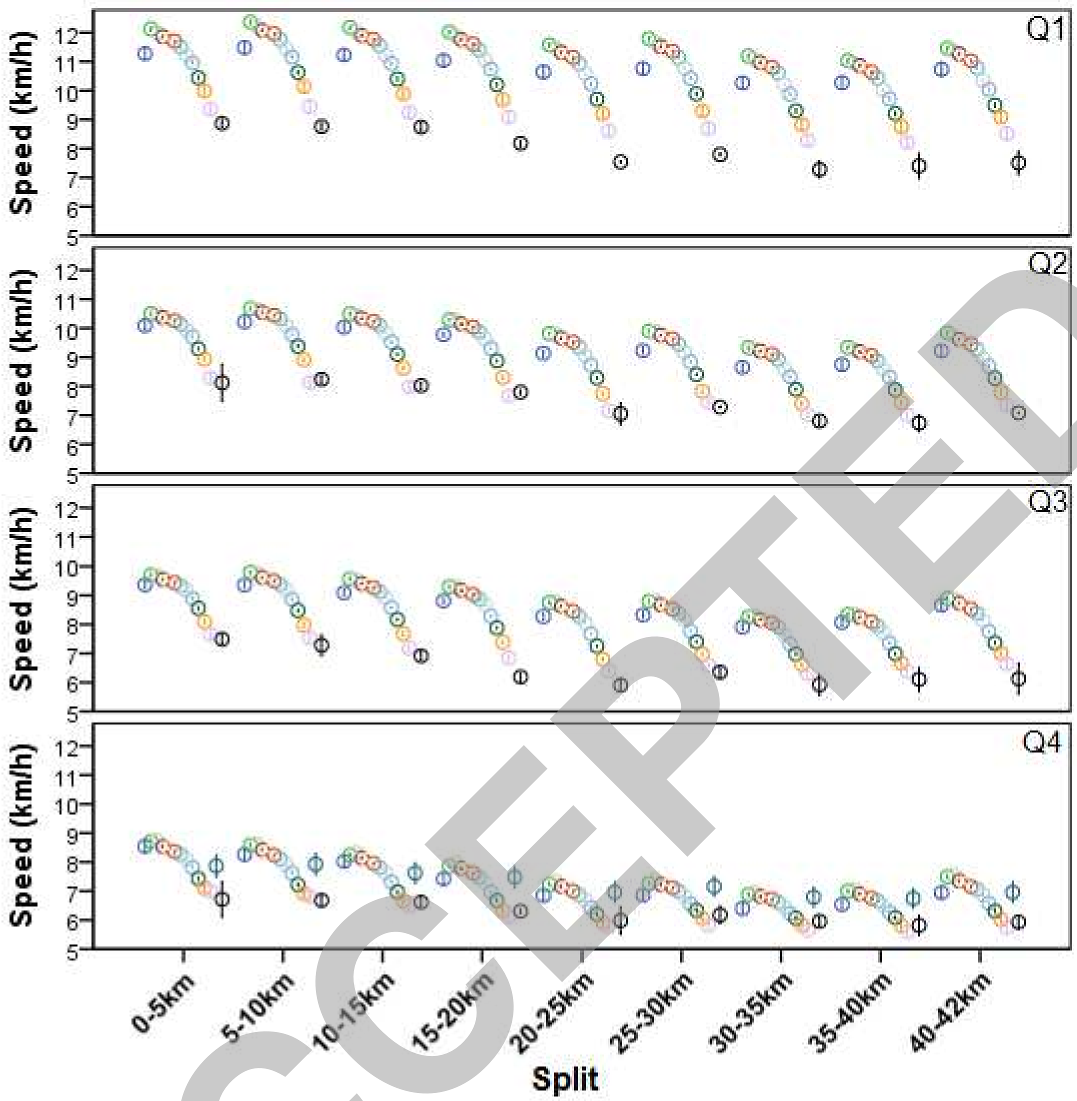

Q1
Q2
Q3
Q4
Speed (km/h)
Split
0-5km
5-10km
10-15km
15-20km
20-25km
25-30km
30-35km
35-40km
40-42km

Figure 4

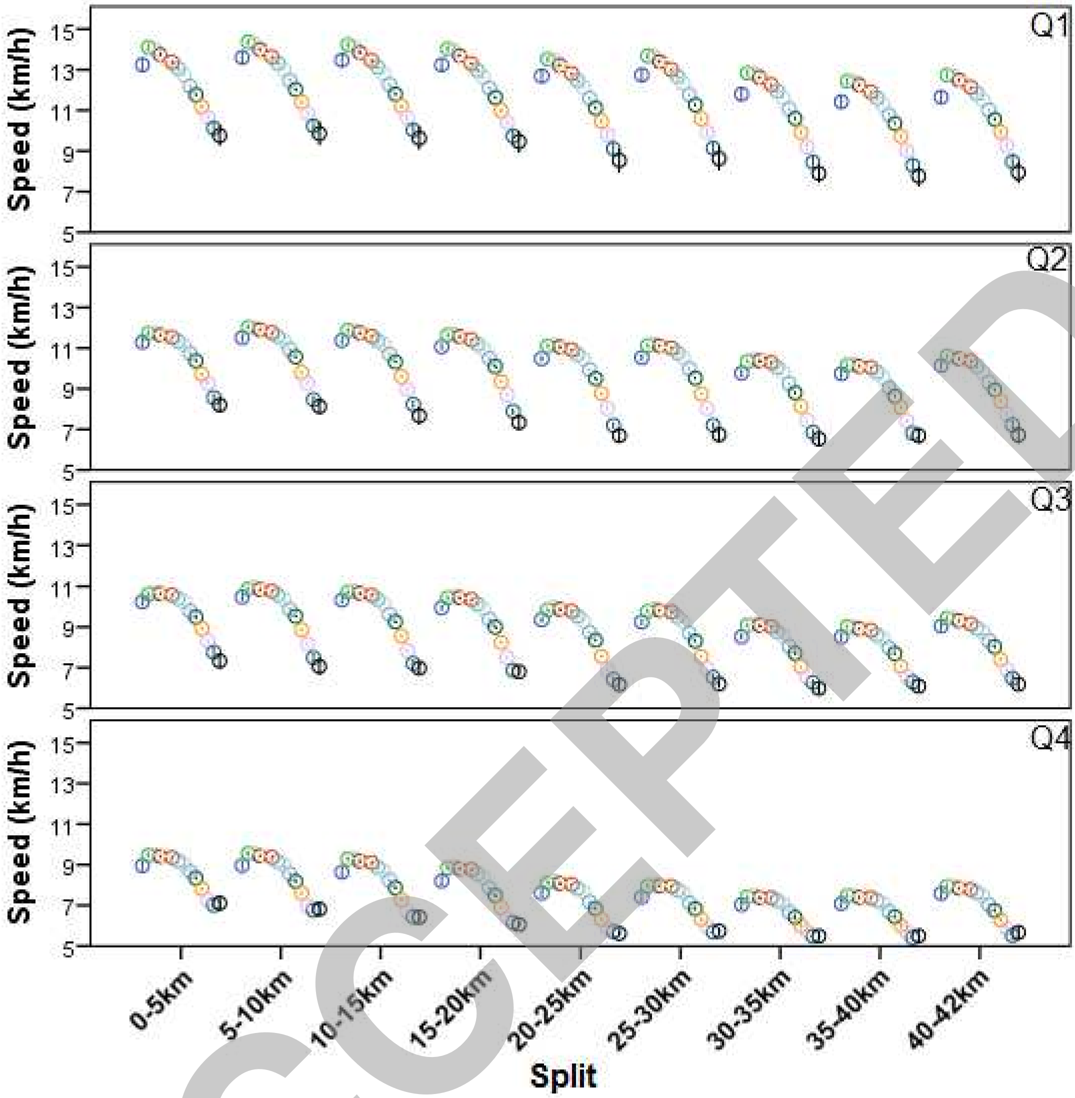

Q1
Q2
Q3
Q4
Speed (km/h)
15
13
11
9
7
5
0-5km
5-10km
10-15km
15-20km
20-25km
25-30km
30-35km
35-40km
40-42km
Split

Figure 5

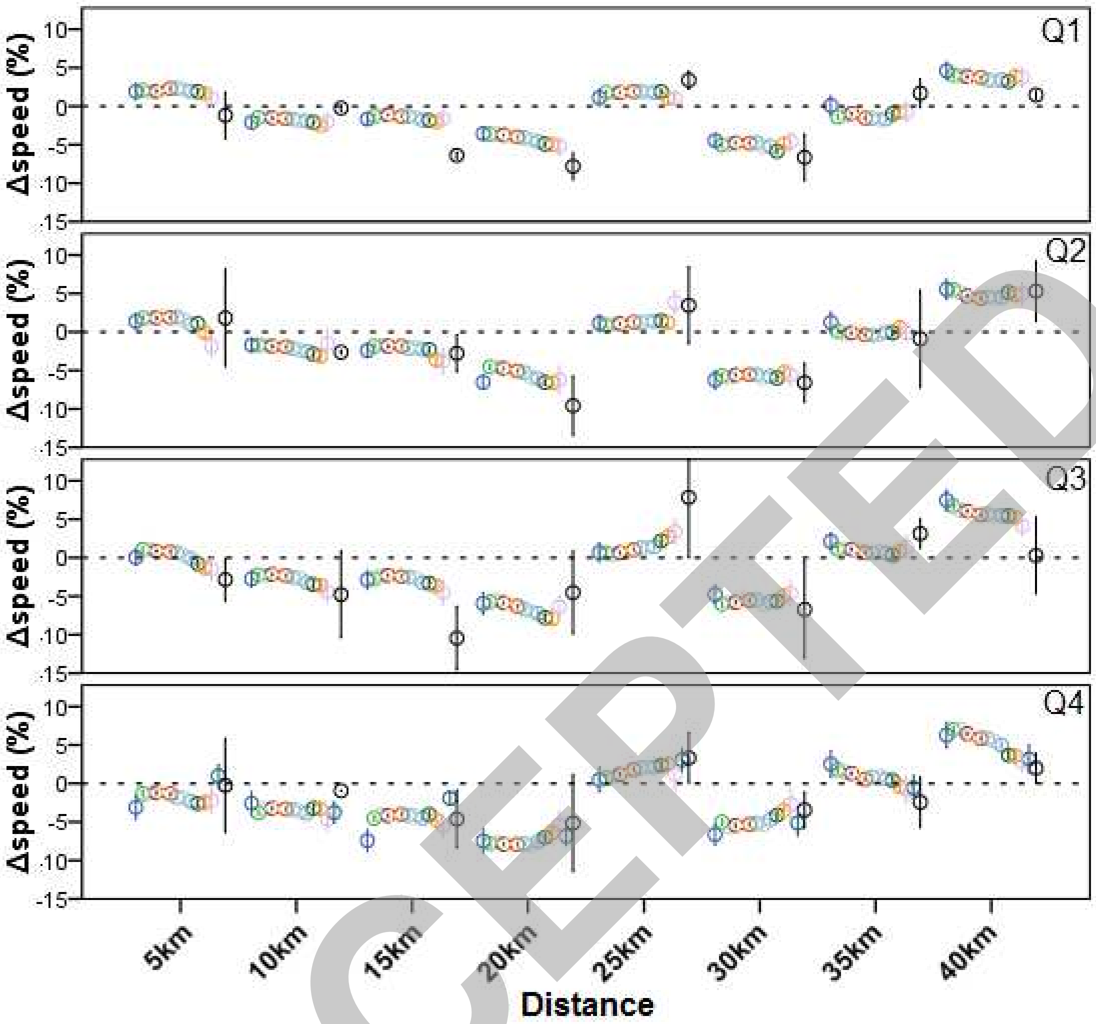
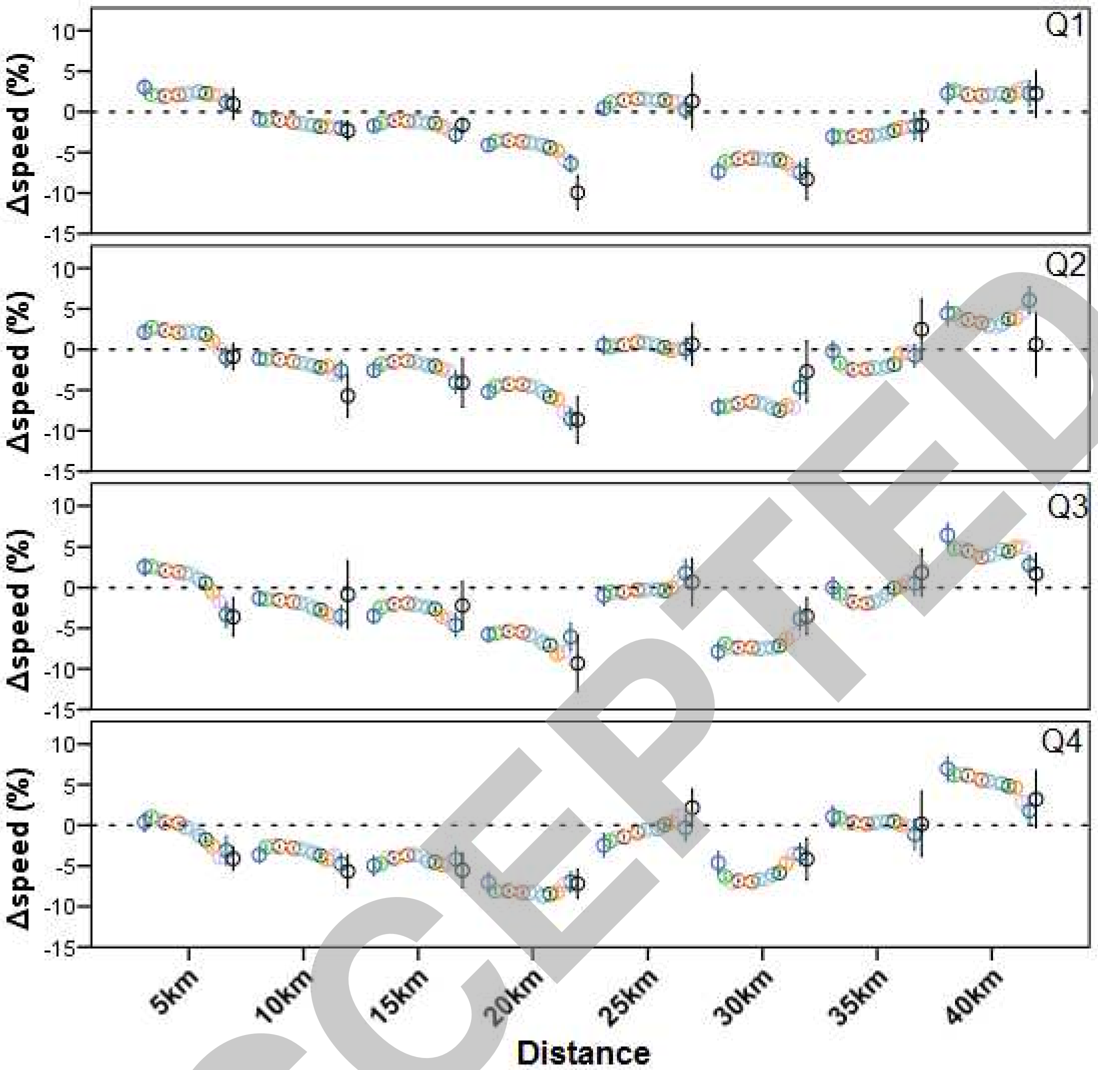
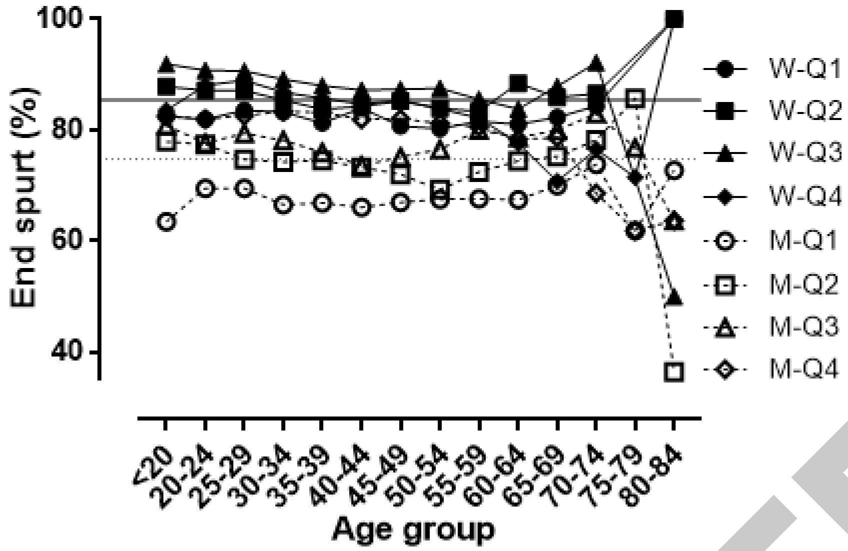

Q1
Q2
Q3
Q4
Δspeed (%)
10
5
0
-5
-10
-15
5km
10km
15km
20km
25km
30km
35km
40km
Distance

Figure 6



Q1
Q2
Q3
Q4
Δspeed (%)
Δspeed (%)
Δspeed (%)
Δspeed (%)
10
5
0
-5
-10
-15
5km
10km
15km
20km
25km
30km
35km
40km
Distance

Figure 7


100
80
60
40
End spurt (%)
W-Q1
W-Q2
W-Q3
W-Q4
M-Q1
M-Q2
M-Q3
M-Q4
<20
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
Age group

